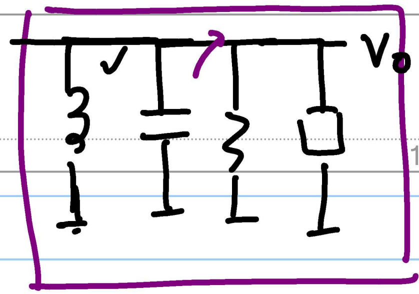
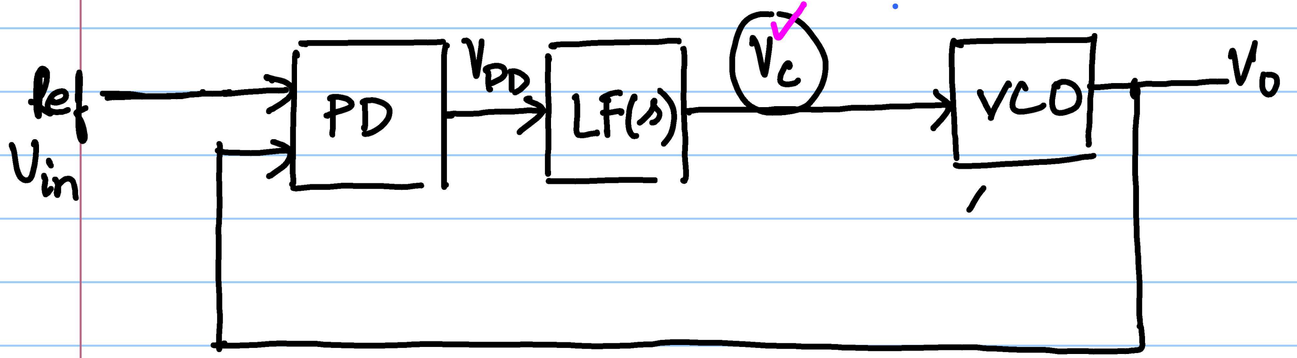
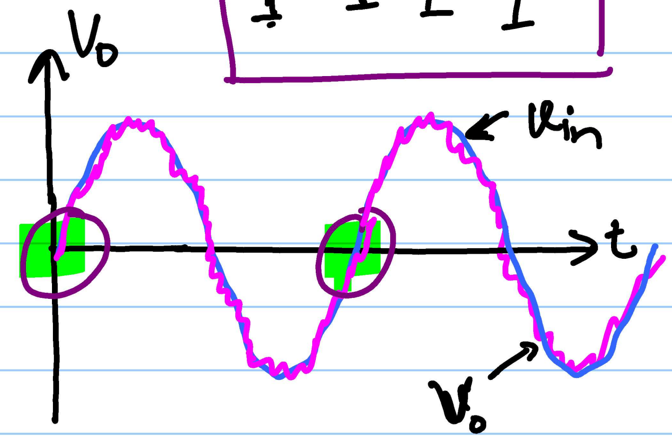
Note Title 11-09-2020

Lecture # 3







VCO: Voltage Controlled Osc.

PD: Phase error detector

LF(s): loop filter.

Ref: Crystal

$v_{in} = a_{in} \sin(\omega_{in} t)$ ✓

$v_0 = a_{out} \cos(\omega_0 t)$ ✓

$\phi_{in}(t) = \int \omega_{in} \cdot dt = \omega_{in} t$ ✓

✓ $\phi_{out}(t) = \int \omega_0 \, dt = \omega_0 t$ ✓

PD: $\phi_{er}(t) = \phi_{in}(t) - \phi_0(t)$

$V_{PD} \propto \phi_{er}$

$V_c \propto V_{PD}$

$\frac{V_c}{V_{PD}} = LF(s)$

$\omega_0 = \omega_{free} + K_{vco} V_c$

$\omega_o = \omega_{free} + K_{vco} \cdot V_c$

ω_o: o/p frequency.

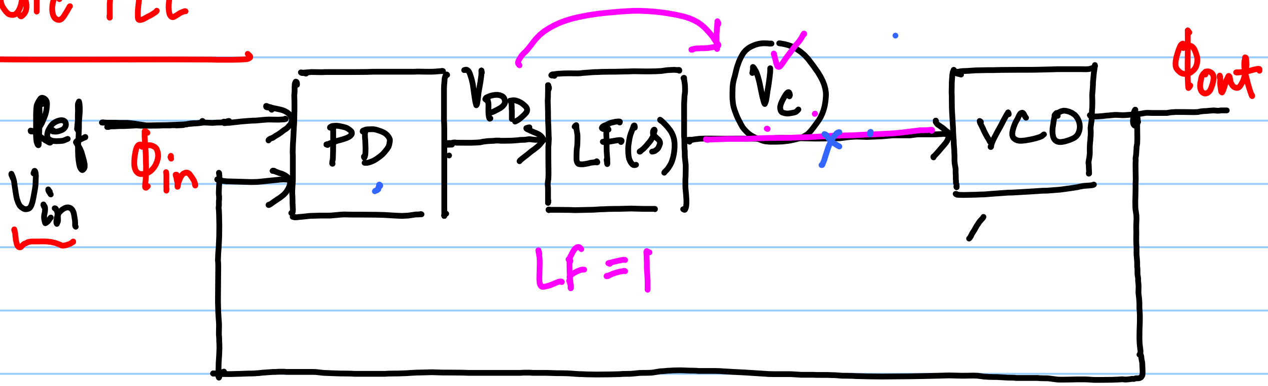
ω_{free}: free running frequency of osc., $V_c = 0$

$K_{vco} = \frac{\Delta\omega}{\Delta V_c}$ $\frac{rad/s}{V}$

$\phi_{er} = (\omega_{in} - \omega_o)\, t$

$\frac{d\phi_{er}}{dt} = 0 \Rightarrow \omega_{in} - \omega_o = 0$

Basic PLL



at t = 0

$\omega_{in} = 1$ Grad/s. ✓

$\omega_o = 0.99$ Grad/s., $V_c = 0$

$\Rightarrow \omega_{free} = 0.99$ Grad/s

$V_{PD} = 0$

$\omega_o = \omega_{free} + K_{vco} \cdot \underbrace{K_{PD} \cdot \phi_{er}}_{V_c} = \omega_{in}$

$\frac{d\phi_{er}}{dt} = 0$

$$V_c = \frac{\omega_{in} - \omega_{free}}{K_{vco}}$$

$\phi_{er}(t) = 10^9 \cdot t - 0.99 \times 10^9 t$ ✓

$= 0.01 \times 10^9\, t$ ✓

$V_{PD} = K_{PD}\, \phi_{er}$ ↑

$\omega_o = \omega_{free} + K_{vco} \cdot V_{PD}$

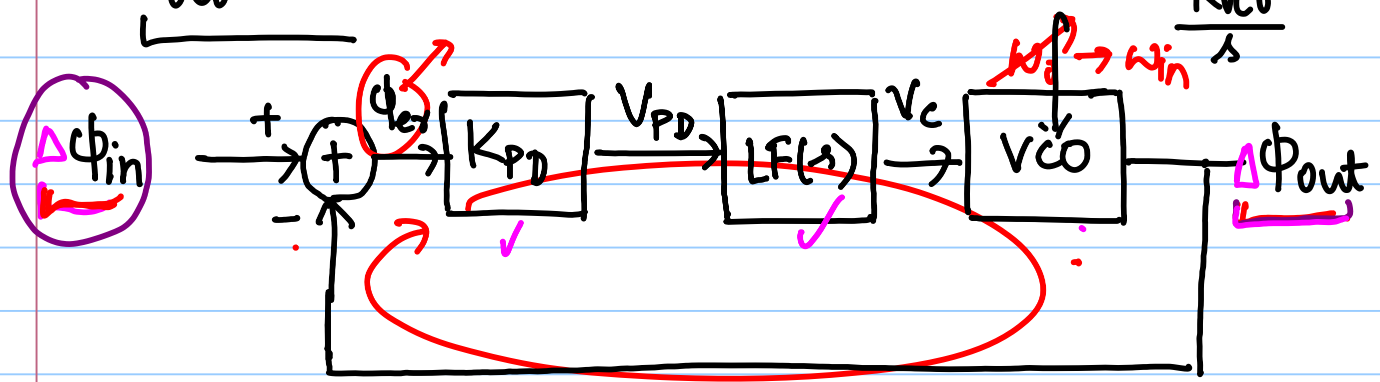
$\omega_o = \omega_{free} + K_{vco} \cdot K_{PD} \cdot \phi_{er}$

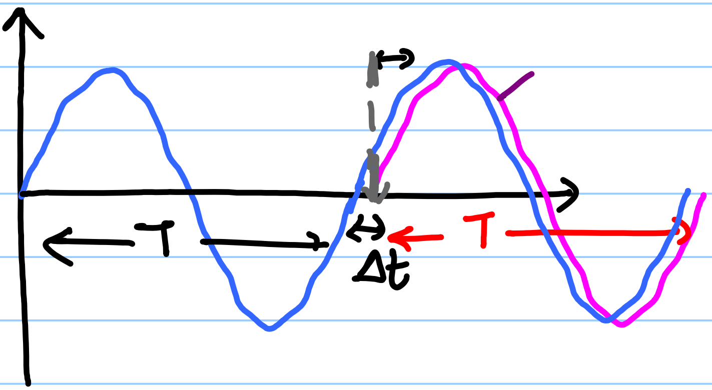
$V_c = K_{PD}\,\phi_{er} \Rightarrow$

$$\phi_{er} = \frac{\omega_{in} - \omega_{free}}{K_{VCO} \cdot K_{PD}}$$

In steady state of PLL:

- $\omega_o = \omega_{in}$
- $\frac{d\phi_{er}}{dt} = 0$ is not same as $\phi_{er} = 0$





$$\phi_{er} = \int \omega_{in}(t) - \omega_o(t)\, dt$$

$\phi_{er}(t) = \omega_{in} t - \int \omega_o(t)\,dt$

$\phi_{er}(t_1) = 0$ | $\frac{d\phi_{er}}{dt} = 0$

$\phi_{in} = \omega_{in} \cdot t$

$\phi_{in}(T + \Delta t) = 2\pi + 2\pi \cdot \frac{\Delta t}{T}$

$\Delta\phi = -2\pi \cdot \frac{\Delta t}{T}$

$$\left.\frac{d\phi_{er}}{dt}\right|_{t=t_1} = \underline{\omega_{in} - \omega_0(t_1)}.$$

$$\left.\frac{d\phi_{er}}{dt}\right|_{t \geq t_1} = 0 \Rightarrow \omega_{in} = \omega_0$$

$$\phi_{out} = \int \omega_o dt = \int (\omega_{free} + K_{vco} \cdot V_c)\, dt$$

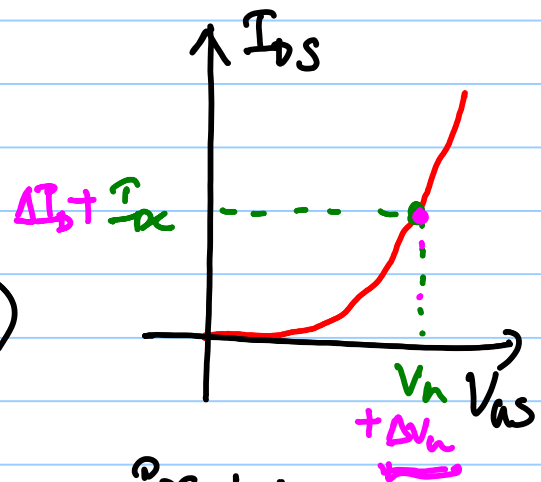
$$\phi_{out} = \omega_{free} \cdot t + K_{vco} \int V_c \cdot dt$$

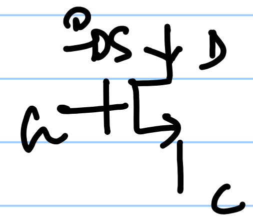
$$\phi_{out} = \omega_{free} t + K_{vco} \cdot V_c \cdot t \quad \text{(In steady state)}$$

$$\Delta\phi_{out}(t) = K_{vco} \cdot \Delta V_c \cdot t$$

$$= K_{vco} \cdot \int \Delta V_c \, dt$$

$$\frac{\Delta\phi_{out}(s)}{\Delta V_c(s)} = \frac{K_{vco}}{s}$$





$$\frac{dI_{DS}}{dV_{GS}} = g_m$$

$$\Delta I_D = g_m \cdot \Delta V_n$$